XXI. *On the Structure of the Dental Tissues of Marsupial Animals, and more especially of the Enamel.*

By JOHN TOMES, *Surgeon-Dentist to the Middlesex Hospital. Communicated by* R. E. GRANT, *M.D., F.R.S., Professor of Comparative Anatomy and Zoology at University College.*

Received June 21,—Read June 21, 1849.

MY DEAR DR. GRANT,

ON making microscopic examinations of the teeth of one or more species of the several families of the marsupial animals, the skulls of which you kindly placed at my disposal, I found some peculiarities of structure, which so far as I know have not hitherto been recognised, and which will I think be found to constitute a pretty constant character in the teeth of this order of quadrupeds. It is my present purpose to describe these peculiarities, and should the communication seem sufficiently interesting and important to engage the attention of the Royal Society, my debt of gratitude, already great, will be rendered yet greater by your lending your name for its presentation.

Professor OWEN, in his Odontography (p. 397), when treating on the structure of the marsupial teeth, says, "The dentine, enamel, and cement of the teeth of marsupial animals, present the usual microscopic characters of these tissues in Mammalia." My researches have led me to a different conclusion. The enamel presents a very strongly-marked peculiarity, common (so far as I have examined), with one exception only, to all marsupial teeth, and present only in a very limited number of other mammalian teeth. I have hitherto found it only in the British Shrews, the Hyrax, and in the molar teeth of the Jerboa.

The main peculiarity to which I allude, is that the greater number, if not all, of the dentinal tubes are continued into, and constitute a considerable portion of the enamel. I have in another place* pointed out that in the human teeth the dentinal tubes are in small numbers, and occasionally only continued for a short distance into the enamel; and the same may be said of many other teeth. In these instances however the condition is rudimentary only, but in the marsupial teeth the development of the tubes in the enamel is as perfect as in the dentine itself. It is not difficult to suppose that a portion of the columns of cells, which constitute the enamel pulp, may become developed into tubes continuous with those formed by the columns of cells in the adherent dentinal pulp, instead of being converted into solid enamel fibres which

* Lectures on Dental Physiology and Surgery, p. 35.

occurs in the majority of teeth; and this no doubt does happen in the marsupial teeth, and also in some few others. Indeed in all teeth the enamel fibre is in an early stage of formation partially tubular*.

I will now proceed to describe the teeth in those species of marsupials that I have examined; for I find many minor points of dissimilarity, by which, on careful comparison, the teeth of allied species may be distinguished the one from the other.

I may remark, however, before doing so, that the enamel presents other points of peculiarity, though less apparent, than its tubularity. In many marsupial teeth the enamel is studded with small cells, often, but by no means always, arranged in contour lines. Then again the fibres are in many teeth so intimately united to each other that their individuality is lost, and this occurs in most teeth in some parts, so that the dimensions of the fibres at such points cannot be taken.

Macropus giganteus.—In this animal the differences in the dental tissues composing the incisor and molar teeth, are chiefly confined to the number of curves described by the enamel fibres and tubes. I shall therefore for the present restrict my description to a transverse section of a lower incisor through the part most thickly coated with enamel.

The dentinal tubes radiate from the pulp-cavity with numerous gentle secondary curves, and when pursuing the latter third of their course before entering the enamel, give off numerous short fine branches. When near the enamel the small branches suddenly cease to be given off, and the parent tubes, either with or without bifurcating, enter the enamel. The absence of the minute lateral tubules renders the tooth more transparent at these than in the neighbouring parts. On entering the enamel the tubes dilate into more or less oval or conical cells, from whence they are continued, and follow in delicate undulations the course of the enamel fibres, some few giving off on their way one or two branches. They gradually diminish in size till they are eventually lost near the surface of the enamel, either from their own minuteness or from their entering small opaque cells, which are common near the outer surface of this texture, Plate XXXV. fig. 1 A, the dentine; B, the enamel. The enamel fibres in the thickest part of the tooth are subject in their course outwards to four, five, and sometimes to even six flexures, fig. 2 B. As they arise from the periphery of the dentine, they proceed upwards in a tolerably straight line towards the cutting margin of the tooth; they then turn downwards at an angle of ninety degrees with their first course, and after advancing about as far in the second as they did in the first line, they describe several lesser flexures having similar angles to the first. When within two-fifths of their termination on the surface, the enamel fibres take a straight and parallel course at right angles with the surface of the tooth.

As the coating of enamel becomes thinner, both towards the cutting edge and at the lower part of the tooth, the lesser curvatures of the fibres are lost, and the direction of the first large flexure is reversed; so that the fibres proceed first downwards

* Lectures on Dental Physiology and Surgery, p. 102.

and then upwards. Near the surface numerous small opaque cells are found irregularly interspersed amongst the enamel fibres, or arranged in contour lines.

In the molar teeth the enamel fibres which arise from the depressions on the masticating surface describe several curves, while those from the sides of the tooth and of the tubercles have but one flexion, and even this is lost where the enamel thins previous to its termination on the neck of the tooth.

The tubes here, as in the incisors, accompany the fibres, but those which arrive near the apex of the tubercles wind round in a spiral course, fig. 3. When the enamel becomes thin previous to its cessation, the tubes are less abundant; and at its termination few, if any, are seen in this or any of the marsupial teeth. When speaking of the enamel in the incisors of the Kangaroo, Professor OWEN says*, "The fibres of the enamel which invest the crown of the large lower incisor are likewise unusually minute; viewed in a transverse section, as in plate 102 *e e*, they describe an abrupt curve at their commencement, and then proceed in a nearly straight course to the surface; but at the trenchant margins of the tooth their course is curved, and they decussate one another, as represented in the figure†. Some of the enamel *lines* at this part seem to be as fine as the dentinal tubes." Professor OWEN has evidently seen the enamel tubes in this tooth, but from some cause has failed to recognise them as such. In the same page he says, "The terminal branches of the (dentinal) tubuli open into minute irregular cells, forming a thin boundary layer between the dentine and enamel." These cells are certainly not between the dentine and enamel in any of the sections I have made, but are distinctly enough visible in the enamel, and form part of the continuous dentinal and enamel tubes.

In conducting the examination of this tooth and of the teeth I am about to describe, I have made at least half-a-dozen sections, taken from different parts and in different directions of the tooth for the purpose of avoiding error.

Professor OWEN states, that the dentinal tubes are the $\frac{1}{13,000}$th of an inch in diameter. In the specimens I have examined, they have averaged $\frac{1}{10,000}$th of an inch at their commencement at the pulp-cavity, have gradually diminished, and on entering the enamel have not exceeded the $\frac{1}{20,000}$th of an inch. On dilating they reach $\frac{1}{6666}$th, and again contract to the $\frac{1}{20,000}$th of an inch, from which they are reduced gradually to the $\frac{1}{30,000}$th and are lost.

The enamel fibres measure $\frac{1}{6666}$th and are cylindrical or oval in their transverse section. The dentinal tubes in the root of the teeth vary in diameter in different parts of their course, and are oval in a transverse section. At their commencement they are the $\frac{1}{8751}$st, but at the middle of their course they reach the $\frac{1}{6000}$th of an inch in diameter, in addition to which they are subject to short local dilatations. In this part of the tooth branches are given off almost from the commencement of the

* Odontography, p. 397.

† Plate 102, fig. 1. "One-half of a transverse section of the lower incisor of a Kangaroo (*Macropus major*), showing the course of the dentinal tubes at *d* and the fine fibres of the thick enamel at *e*."

tubes; these recurve and present their convexities towards the outer surface of the tooth.

Near the surface the dentinal tubes break up into an infinite number of delicate branches, resembling tufts of fine moss, effecting at the same part innumerable anastomoses. At and near the extremity of the fang, short branching dentinal tubes are interspersed with cemental cells, but higher up, towards the crown of the tooth, the cement and dentine are separated by a well-defined line of demarcation, across which a few only of the tubes advance to join the branches of the neighbouring cemental cells.

Near the neck of the tooth the cemental cells are often altogether wanting in branches, and approach a circular form.

Hypsiprymnus minor and *penicillatus*.—The teeth of these animals resemble very closely in structure those of the Kangaroos. In the incisors, the enamel being less thick, present but one curve, and that in the direction of the axis of the tooth.

In *Hyp. penicillatus*, the dentinal tubes, on entering the enamel, dilate into irregularly oval or circular cells, measuring about $\frac{1}{10,000}$th of an inch in diameter; they then suddenly contract to $\frac{1}{30,000}$th, and follow the course of the enamel fibres to near the surface; then some few bend to a right angle with their original course and terminate in a point, their terminal course being directed towards the root of the tooth, fig. 4. The fibres of the enamel measure $\frac{1}{7500}$th of an inch in diameter.

The dentinal tubes at their commencement at the pulp-cavity measure the $\frac{1}{12,000}$th, and at the point where they enter the enamel the $\frac{1}{30,000}$th of an inch.

In *Hypsiprymnus minor*, the dentinal tubes, on entering the enamel, often do not dilate at all, and when they do, the dilatation is continued for some little distance with an irregular outline. Hence, on accurate comparison, the teeth of the one species of Hypsiprymnus may be distinguished from those of the other.

Phascolomys Wombat.—The teeth of this interesting marsupial are remarkable for the complete absence of tubes in the enamel. The dentinal tubes cease at the line of junction of the dentine with the enamel, and in no case pass across into the enamel. The fibres of the latter texture are clear and transparent; and arising from the peripheral surface of the dentine, after presenting one or two slight undulations, arrive at the surface of the enamel, which in the incisor teeth is invested with a thin layer of cement. The enamel fibres measure about the $\frac{1}{7500}$th of an inch in diameter. Their course is not, as regards each other, everywhere parallel; on the contrary, at certain points intervals will be left by their divergence, which are filled up by supplementary fibres; then again bundles of fibres converge and cross each other. I have failed to observe the transverse striæ mentioned by Prof. Owen*. The fibres have sometimes a slightly irregular outline, which gives an appearance of unequal dimensions to different parts of the same fibre, and not unfrequently longitudinal central lines may be seen, like the persistent nuclei of the developmental cells.

* Odontography, page 398.

The dentinal tubes are, at the pulp-cavity, about the $\frac{1}{10,000}$th of an inch in diameter, and at the peripheral ends $\frac{1}{30,000}$th of an inch. The tubes, as they leave the pulp-cavity, advance upwards towards the surface of the tooth, but in the latter part of their course they bend outwards, and thus describe large curves, the convexities of which are directed towards the masticating surface. Until within the $\frac{1}{375}$th of an inch of the enamel the dentinal tubes give off very few branches, but when they have arrived at that point, and for a short distance onward, they give off numerous tubules which form a dense meshwork of tubes in a contour line with the enamel, fig. 5.

Professor OWEN, in the work already referred to—the standard work on Odontography in our language,—mentions that medullary canals are prolonged into the substance of the dentine, and also that many of the dentinal tubes terminate in cells on the periphery of the dentine. Of this I have now to speak.

Out of this meshwork of branching and anastomosing tubes a few are continued into a comparatively clear space about the $\frac{1}{750}$th of an inch broad, and terminate either in irregular cells which vary from the $\frac{1}{6000}$th to the $\frac{1}{15,000}$th of an inch in diameter, or by anastomosis. None however cross into the enamel. That portion of the tooth which lies towards the mouth is not invested with enamel, but is covered by a thin layer of cement, between which and the dentine there is no distinct line of demarcation. Into the cells of this run the terminal branches of the dentinal tubes. The cement is continued over the surface of the enamel in a layer of about the $\frac{1}{750}$th of an inch in thickness, and this is tenanted by a single line of cells.

These teeth closely resemble, as well in structure as in external form, those of the Rodents, and especially the Hare and Rabbit.

Phalangista vulpina.—The dentinal tubes of the molar teeth of this creature arise at the pulp-cavity, with a diameter of about the $\frac{1}{10,000}$th of an inch, and pursue a slightly undulating course until they have accomplished two-thirds of their whole distance; they then bend downwards from the crown, and give off innumerable minute tubules. When within a short distance of the enamel they dichotomize once or twice, and enter that structure with a diameter of about the $\frac{1}{30,000}$th of an inch, fig. 6.

On passing into the enamel the tubes occasionally dilate into an oval or oblong cell of from the $\frac{1}{7500}$th to the $\frac{1}{10,000}$th of an inch in diameter, but far more commonly they undergo no dilatation. Others again dilate into an oval or long cell. When they have passed half or two-thirds through the enamel, some few divide once or twice into two branches. After following an undulating course until near the surface of the tooth, they terminate in small cells or become imperceptibly minute. The tubes in the enamel have a diameter varying from the $\frac{1}{15,000}$th to the $\frac{1}{20,000}$th of an inch.

The dentinal tubes, near their commencement at the pulp-cavity, in about the middle part of the fang, commonly reach a diameter of the $\frac{1}{6000}$th of an inch. They give off branches during the whole of their course, and terminate in a dense anasto-

mosing plexus of tubes, from which many pass to the cells of the cement; hence these two tissues are not separated from each other by a strongly-marked line of demarcation, such as obtains in some other teeth of marsupial animals.

Petaurus taguanoides.—The molar teeth of this interesting animal, though possessing the marsupial characteristic strongly marked, yet are so different under the microscope from those I have already described as to be recognised at first sight. The dentinal tubes at their commencement at the pulp-cavity have a diameter not exceeding the $\frac{1}{15,000}$th of an inch. They follow a slightly undulating course to about two-thirds of their length; they then make one large curve, the concavity of which is usually directed towards the crown of the tooth. At no part of their course do the dentinal tubes of the crown give off branches until they arrive at the enamel; then a few, and a few only, divide into two branches, and are continued into that tissue. The tubes, on entering the enamel, make a small curve downwards, corresponding in direction to that in the dentine just described; they then follow an upward course, and are lost near the surface. The tubes usually suffer no change of dimensions on passing into the enamel, but generally keep a diameter of about $\frac{1}{60,000}$th of an inch, till they are lost in small opaque markings that are common in the enamel near its surface, Plate XXXVI. fig. 7.

The dentinal tubes of the fangs of these teeth are perceptibly larger than those of the crown, and very commonly have a ragged outline, or are composed of lines of cells. They give off but comparatively few branches, and these only near the surface of the fang.

In the incisor teeth the dentinal tubes branch more abundantly than in the molars, and are less frequently continued into the enamel.

In the fangs of the lower incisors the tubes are distinctly oval in section, having a greater diameter of $\frac{1}{7500}$ and lesser of $\frac{1}{15,000}$. The final large curve also has its convexity directed towards the crown of the tooth.

Petaurus sciureus.—The structural characters of the teeth of this animal closely resemble those of *P. taguanoides*. There are however differences by which, on comparison, the one may be known from the other. The dentinal tubes in their course from the pulp-cavity towards the crown arch with the convexity directed upwards; then again they give off numerous fine branches during the latter third of their course. In the fangs they dichotomize during the latter half of their length, but do not form the rich plexuses of tubes common in the Kangaroos; neither do the branches go off at a right angle; on the contrary, they follow much the same course as the parent tube. The fang is plentifully supplied with cement, which contains a few cells of very elongated form, with the long axis in the direction of that of the tooth. In addition to these there are great numbers of tubes placed parallel with each other, and at right angles with the surface of the tooth.

Dasyurus ursinus.—The dentinal tubes of the crown of the tooth advance at a right angle with the surface of the pulp-cavity. Those which form the upper part of the

crown proceed upwards, then in a large curve bend outwards, and when within the $\frac{1}{1000}$th of an inch of the enamel give off an abundance of short fine tubules, and when so doing turn upwards, having but few previously, and none at all until within half-way of the enamel. On entering the enamel they again make a small curve downwards, give off occasional branches, and make numerous short deflections downwards, and after advancing through about two-thirds of the thickness of the enamel are lost, fig. 8.

The tubes at the pulp-cavity measure about $\frac{1}{10,000}$th of an inch in diameter, and on entering the enamel $\frac{1}{30,000}$th of an inch; when within the enamel they increase to about the $\frac{1}{20,000}$th, and gradually diminish till they become invisible, or are lost in small cells. On the lingual surface of the tooth, the tubes in this, as in many other marsupial teeth, commence by small cells.

The dentinal tubes of the fangs are lost in the cement, between which and the dentine there is no strongly-marked line of demarcation. The cemental cells are large, elongated in figure, and have many and large tubules.

In the molar teeth of *Dasyurus macrourus* the dentinal tubes branch more sparingly, and on entering the enamel are not subject to the same degree of deflection, though possessed of the same general character as those seen in the *D. ursinus*; neither do they suffer any enlargement in the first part of their course, as is common in the last-mentioned tooth, fig. 9.

The cemental cells are more simple in form, and the dentine and cement are separated by a well-marked line of junction, except at the apex of the fang, where the cement is reflected for a short distance up the canal.

In the canine teeth of this animal a considerable portion of the lower end of the fang is made up of cement. In the concave lingual surface of the crown the enamel is thin, and the tubes frequently commence in small cells. The dentinal tubes give off small branches during the greater part of their course, and when close to the enamel occasionally turn upward and dilate into elongated cells.

Thylacinus cynocephalus.—The teeth of this creature have a strong family resemblance to those of the *Dasyuri* last described. There are however minute points of difference. The dentinal tubes, in addition to giving off minute short pilose branches, on nearing the enamel divide into several large branches, fig. 10 A. They are likewise more disposed to dilate on entering the enamel, though many proceed without marked increase of size. Then, again, the tubes are lost by the time they have gained the inner fifth of the whole thickness of the enamel; and the enamel fibres are more distinctly marked than in either of the preceding species excepting the Wombat, thereby approaching in structure to the teeth of the ordinary carnivora, fig. 10. The dentinal tubes, on leaving the pulp-cavity to proceed towards the coronal surface, have a diameter of about the $\frac{1}{10,000}$th of an inch; on reaching the periphery the $\frac{1}{42,857}$th, and in the first part of their course in the enamel the $\frac{1}{20,000}$th. Those destined for the upper part of the crown advance upwards, and then make one large

bold curve outward, with the convexity directed upwards; in the fang they make a second large curve with the concavity directed upwards.

The tubes, when in the enamel, in addition to a multitude of minute undulations, describe one large curve with the concavity directed upwards. They for the most part rapidly diminish in size; sometimes, however, they dilate into small cells, and again continue their course. Previous to terminating some few give a number of small branches from their convex side (fig. 10 B), which rapidly diminish in size and are lost. At about the point where the tubes are lost the enamel fibres become tolerably distinct, though with a somewhat ragged indefinite outline. Their diameter is about the $\frac{1}{10,000}$th of an inch; and they take a tolerably direct course outwards. I have stated that the enamel fibres of the tooth of the Thylacinus resemble in a slight degree those of ordinary carnivora, but the one structure cannot for a moment be mistaken for the other, see figs. 10 and 11. Small cells are scattered through the enamel of the Thylacinus and near the surface in contour lines.

The dentinal tubuli of the fang terminate in a granular layer, which, excepting near the extremity of the fang, is separated from the cementum by a strongly-marked boundary line.

The cells of the cementum have no peculiarity; they are arranged in linear series, their long axes being in the direction of that of the tooth. The cement is tolerably abundant in quantity, and at the apex of the fang is pierced by canals for vessels.

Didelphis virginiana.—The teeth of this species were from the skull of an old animal, and though much worn by use yet sufficient remained for my purpose. The marsupial characters, so far as I have had the means of observing, are strongly marked. The dentinal tubes on leaving the pulp-cavity have a diameter of about the $\frac{1}{15,000}$th of an inch. Those that are destined for the masticating surface make one or two large in addition to numerous gentle secondary undulations. But all that depart for the sides of the crown or the tubercles, make a curve on nearing the enamel, the concavity of which is directed upwards, fig. 12 A. During this part of their course they give off from either side, but more especially from the convex side, numerous small, short, delicate branches. Finally, they break up into several branches, which on passing into the enamel preserve their dimensions, the $\frac{1}{42,857}$th of an inch.

When within the enamel the tubes advance to near the surface, which, as the enamel is not thick, is no great distance. In their course, they are subject, in addition to small undulations, to one or two deflections, the concavities of which are directed towards the grinding surface of the tooth, and some few give off one or two branches.

The cementum is abundant, and contains numerous highly developed cells, which give off many branching and anastomosing canaliculi, which form a tolerably uniform meshwork of tubes throughout the whole mass. The extremities of the fangs are constituted of cement, through which anastomosing canals for vessels pass towards the pulp-cavity. The cementum and dentine, though separate at some parts, at

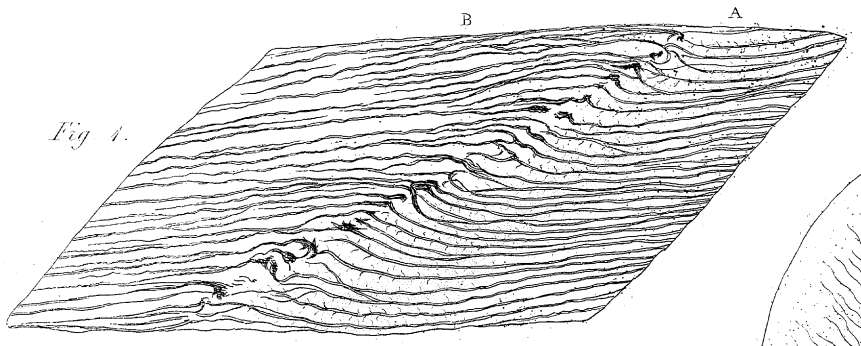


Fig. 1.

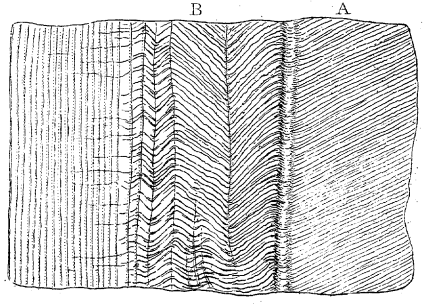


Fig. 2.

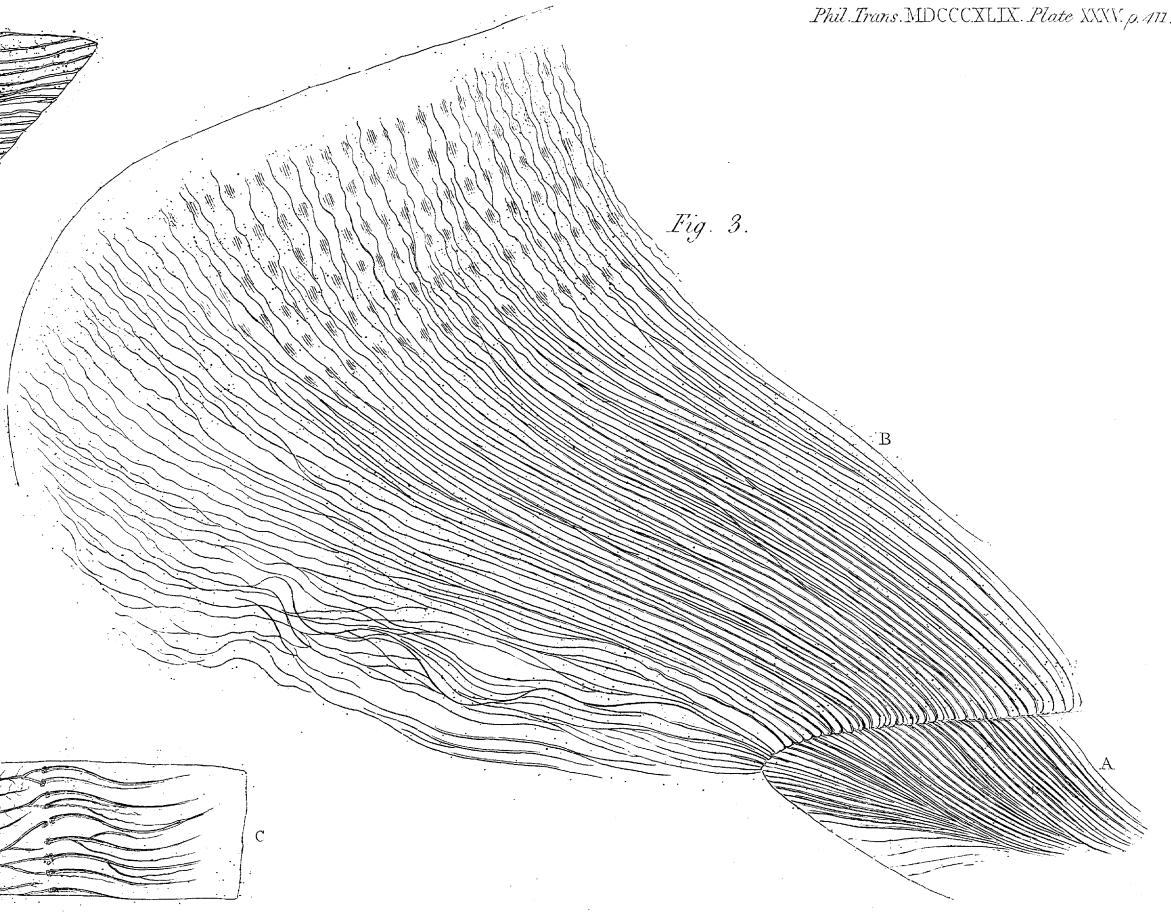
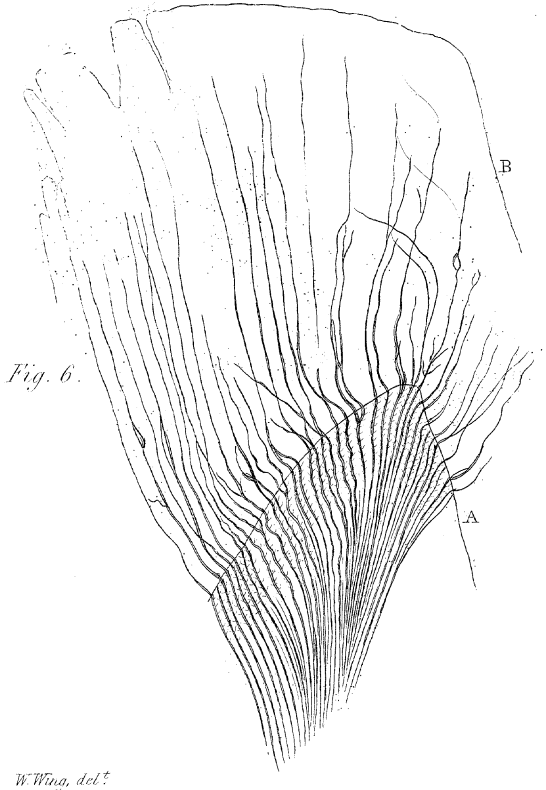


Fig. 3.

Fig. 4.



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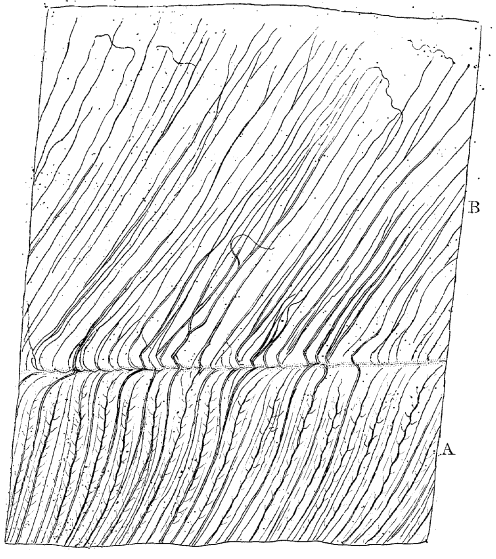

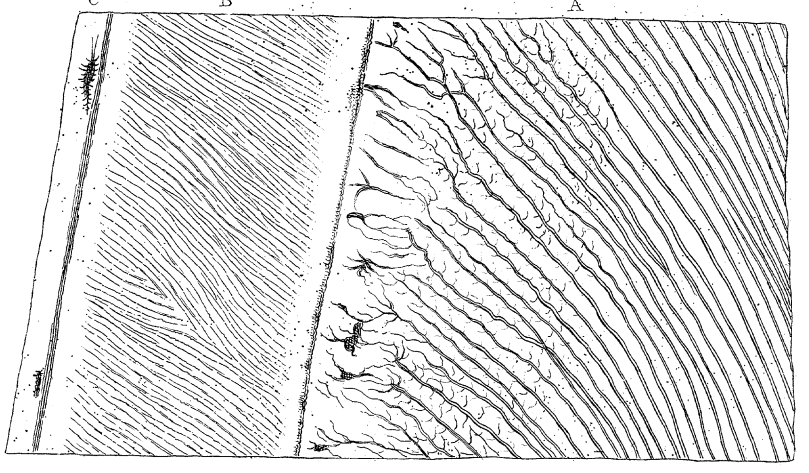

Fig. 5.

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others pass into each other, and are so gradually and intimately blended that it would be impossible to determine to which tissue a given point belonged.

The facts that I have stated lead, I think, to two conclusions. First, that the existence of fully developed tubes in the enamel continuous with those of the subjacent dentine, is common to the teeth of at least the great majority of marsupial animals, if not all, excepting the Wombat. And, secondly, that the enamel and dentine are so closely related, that the one should almost be regarded as a modification of the other, rather than as a tissue of a wholly different nature.

The sections from which the foregoing descriptions have been written, form part of an extensive series in my possession. The accuracy of the statements may therefore at any time be tested.

I remain, my dear Sir, yours faithfully,

June 20th, 1849. JOHN TOMES.

To Robert E. Grant, M.D., F.R.S.

EXPLANATION OF THE PLATES.

PLATE XXXV.

Fig. 1. A section from crown of a molar tooth of *Macropus giganteus*, showing the tubes of the dentine A in the latter part of their course, and continued into the enamel B, that part only near the dentine being shown. C, a continuous dentinal and enamel tube more highly magnified.

Fig. 2. A transverse section through the lower incisor of the same animal. A, the dentine. B, the enamel in its whole thickness, showing the curves of the fibres.

Fig. 3. The apex of one of the tubercles from the crown of a molar tooth of *Macropus giganteus*, showing the whole thickness of the enamel, B, containing cells in the contour lines, and showing also the spiral course of the enamel tubes near the apex of the tubercles. A, the dentine.

Fig. 4. A longitudinal section from a premolar tooth of *Hypsiprymnus penicillatus*, showing the outer part of the dentine A, and the whole thickness of the enamel B, with the tubes in each. C, the same more highly magnified.

Fig. 5. A longitudinal section from a lower incisor of the Wombat, showing the dentine A, with the manner of termination of the dentinal tubes. B, the enamel, and C, the cement.

Fig. 6. A longitudinal section of a tubercle from a molar of *Phalangista vulpina*, showing A, the dentine, and B, the enamel with their tubes.

PLATE XXXVI.

Fig. 7. A longitudinal section from the crown of a molar tooth of *Petaurus taguanoides*, showing A, a portion of the dentine with its almost branchless dental tubes, and B, the enamel in whole thickness.

Fig. 8. A longitudinal section from the tooth of *Dasyurus ursinus*, showing a portion of the dentine A, and the whole thickness of the enamel B, with the tubes of each.

Fig. 9. A similar section of the tooth of *Dasyurus macrourus*.

Fig. 10. A longitudinal section of the last molar from the lower jaw of *Thylacinus cynocephalus*, showing A, a portion of the dentine, and B, a portion, but not the whole thickness of the enamel.

Fig. 11. A section from the canine tooth of the Leopard, showing A, the peripheral part of the dentine, and B, the enamel. The latter is typical of the enamel of the ordinary carnivora, the fibres of which measure the $\frac{1}{5000}$th of an inch in diameter*.

Fig. 12. A longitudinal section of a molar tooth of *Didelphis virginiana*, showing A, the dentine at its termination, and B, the enamel in its whole thickness, with the tubules in each texture.

* This figure is introduced to show the differences between the enamel in the ordinary carnivora and in the marsupial carnivora.

Fig. 7.

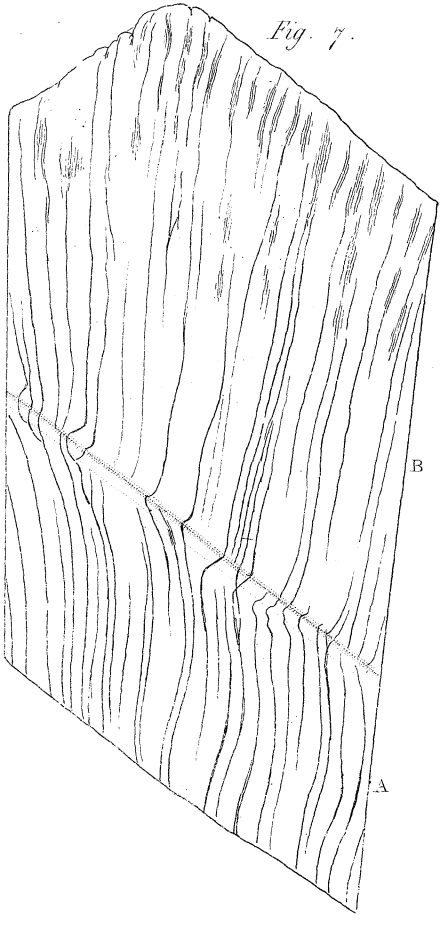
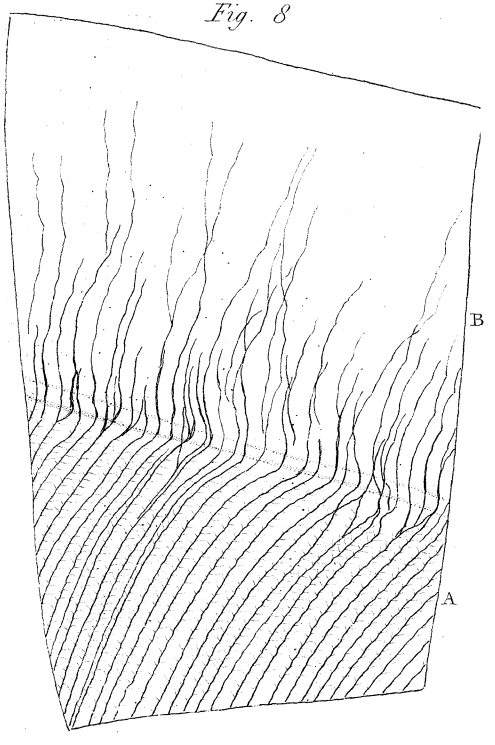


Fig. 8



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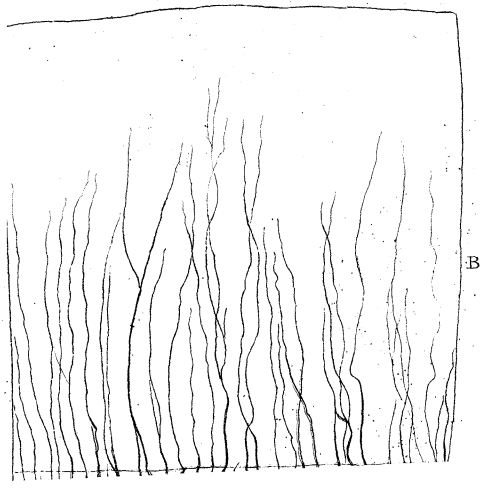


Fig. 10.

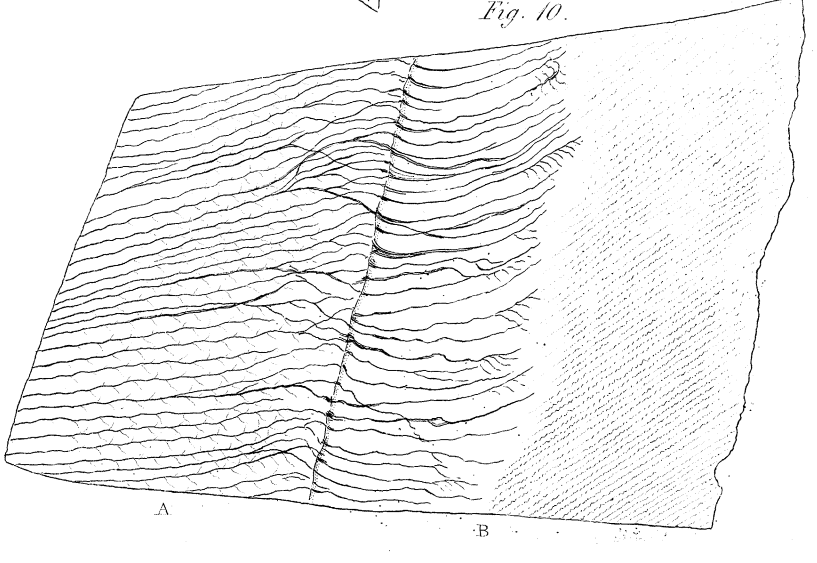


Fig. 11.

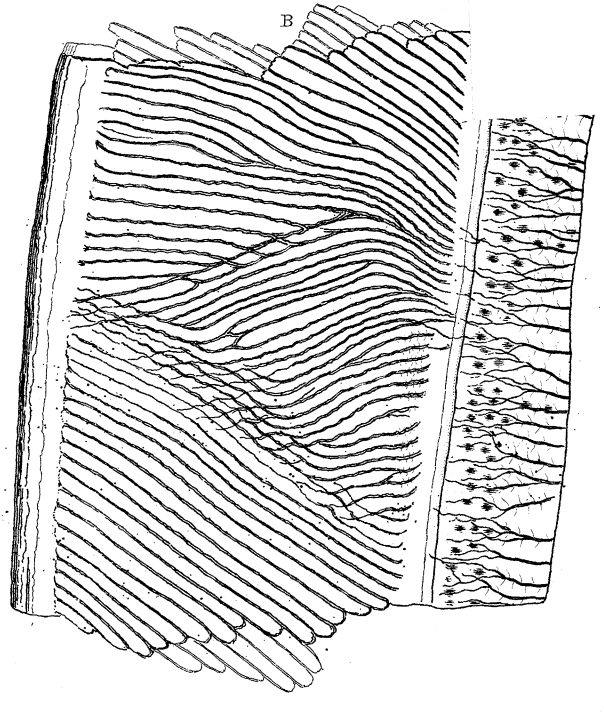
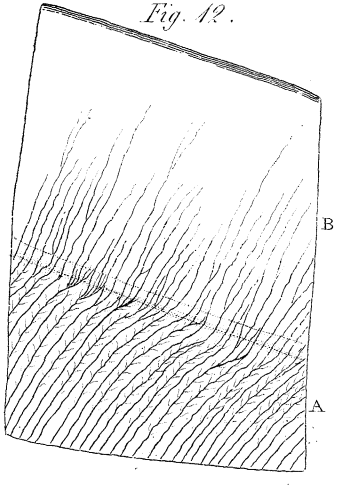


Fig. 12.



W Wing del.

J. Basire sc.